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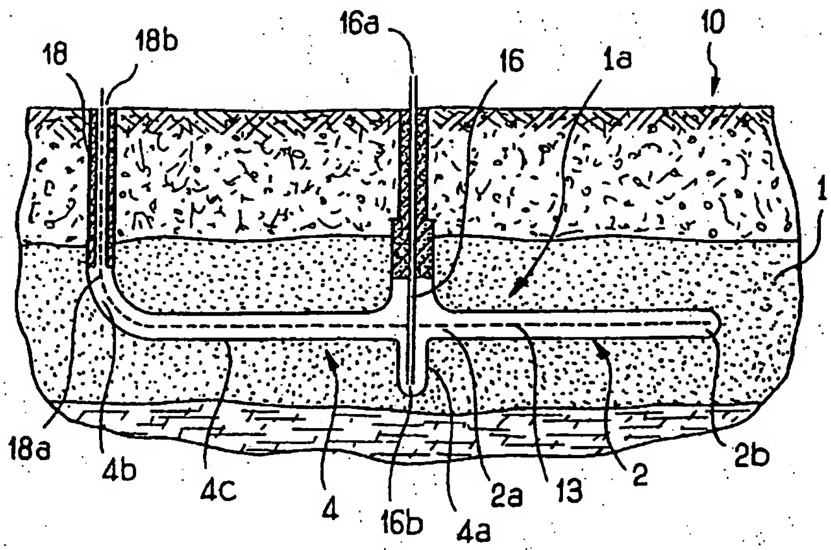
(54) **PROCEDE D'EXCAVATION SOUTERRAINE DANS UNE MINCE FORMATION DE SEL**

(54) **PROCESS FOR EXCAVATING A CAVITY IN A THIN SALT LAYER**



(57) Cette invention concerne un procédé d'excavation par dissolution dans une mince couche souterraine de sel afin de constituer un réservoir de stockage de liquide. Selon la présente invention, le procédé comprend les étapes suivantes : création d'un conduit d'injection (16), d'un conduit d'extraction (18) et d'un vide (4) matérialisant un passage (14) reliant les deux conduits; création d'au moins un tunnel-impasse (2) communicant avec le passage pour permettre la circulation d'un solvant et la dissolution du sel dans le tunnel-impasse; injection d'un solvant dans le passage via le conduit d'injection; et extraction de la saumure obtenue via le conduit d'extraction. L'avantage de cette solution réside dans le fait que l'excavation conserve une forme structurellement stable pour un volume plus important et qu'elle est plus économique à réaliser que selon les méthodes connues.

(57) The invention concerns a process for excavating by dissolution an underground cavity in a thin salt layer, in order to store a fluid therein. According to the invention, the process comprises the following steps: - producing an injection duct (16), an extraction duct (18), and a void (4) for a communication space (14) which places in communication the injection and extraction ducts;
- producing at least one blind tunnel void (2) communicating with the communication space so as to enable the solvent to circulate and the salt to dissolve in the blind tunnel; - injecting via the injection duct a solvent in to the communication space; and - extracting via the extraction duct the brine formed by the dissolution of the salt on contact with the solvent. The advantage of this solution is that the layer excavated has a mechanically stable shape and a larger volume and is produced more cheaply than with the prior art.

The invention concerns a process for excavating by dissolution, an underground cavity in a thin salt layer, for example an underground salt layer.

More particularly, the invention is concerned especially with obtaining, after excavation, a cavity for the storage of a fluid, in particular natural gas, in a salt cavern obtained after the dissolution process.

In view of the stresses to which the cavity has to be subjected during its use as an underground gas storage, the dissolution process has to be controlled in order to ensure that the final cavity has a mechanically stable shape.

Although it is relatively easy to control dissolution when the thickness of the available salt is several hundred meters thick or so, this operation is more awkward when the salt is stratified and of more reduced thickness. In fact, even when the thickness of the salt available is only a few hundred metres thick, it becomes necessary to apply specific cavern dissolution processes to develop cavities whose width over height ratio is of the order of 1. When the salt thickness is less than about 100 metres, new salt dissolution processes are needed. The invention

concerns a process for developing a tunnel-shaped cavern in such a thin salt layer.

Certainly, US-A-5 246 273 discloses for the excavation of a salt layer by dissolution:

- producing an injection duct, an extraction duct, a void for a communication space which places the injection and extraction ducts in communication, and at least one void for a blind tunnel such that:
  . the blind tunnel extends between an open end and a closed end; and
  . the blind tunnel communicates via its open end with the communication space;
- then injecting via the injection duct a salt solvent into the communication space in order to excavate the cavity by dissolution of the salt on contact with the solvent; and
- then extracting via the extraction duct the brine formed by the dissolution of the salt.

In this document, US-A-5 246 273, the communication space and the blind tunnel are excavated as an extension of each other, sloping downwards from the injection shaft such that the closed end of the injection shaft is lower than its open end. The blind

tunnel is an optional sump designed to recover the insoluble elements deposited therein.

Consequently, the technique applied in US-A-5 246 273 is costly since, related to the volume of the final cavity with a mechanically stable shape, the number of production operations is relatively high (in particular producing the ducts and the void for the communication space).

In order to overcome these problems, the invention proposes that, to excavate the cavity, the blind tunnel also be excavated by circulating the solvent in this tunnel, making the solvent pass into the tunnel via its open end from the communication space and recovering the resultant brine so that it can be extracted therefrom.

As will be appreciated, a blind tunnel is a tunnel which is distinct from the communication space and has a single end communicating with said space.

The advantage of this solution is in particular that it permits a varied range of cavity forms and allows the cavern to be worked in numerous directions.

Consequently this solution enables the volume of the final cavity to be substantially increased without having to move the injection or extraction ducts, whilst preserving a certain degree of mechanical stability. The cost of the excavation operation related to the volume of the cavity is therefore reduced.

It is thus highly advantageous to increase the number of blind tunnel voids connected to the communication space.

This solution is all the more noteworthy since it has an unexpected effect. Indeed, a blind tunnel *a priori* does not encourage the intake and circulation of the solvent, even less so the mixing of the solvent and dissolution of the salt. However, this is what happens in practice.

Throughout the description the term "void" designates the initial state of a space or tunnel (before the solvent dissolves the salt). It could correspond to a preliminary borehole.

According to one preferred embodiment of the invention, in order to improve dissolution in the blind tunnel, the closed end thereof is disposed at a

level which is higher than or substantially the same as that of the open end.

Since the density of the brine is higher than that of the solvent, when the closed end of the blind tunnel is disposed at a lower level than that of the open end, the brine tends to stagnate at the closed end of the blind tunnel. Therefore the solvent no longer circulates in the blind tunnel and the excavation thereof by dissolution tends to stop. This phenomenon is all the more notable, the more pronounced the slope and the longer the blind tunnel.

In order to improve further the dissolution action in the blind tunnel, at the point of connection between the communication space void and the blind tunnel void (which point could *a priori* be disposed anywhere along the communication space void between the two ducts), the open end of the blind tunnel void may be produced such that it overhangs the communication space.

A variant likewise enabling the dissolution action in the blind tunnel to be improved may involve:

- forming the open end of the blind tunnel void in the vicinity of the injection duct;
- circulating the solvent in the injection duct and making it emerge from this duct via an end which forms

the point of injection into the cavity; and

- forming the blind tunnel void such that the part with its open end overhangs the injection point.

According to another embodiment of the invention, in order to improve further the dissolution in the blind tunnel:

- the injection and extraction ducts are produced at a spacing from each other;

- an elongate part is provided in the communication space void; and

- the void for the blind tunnel and the elongate part of the communication space void are produced substantially as an extension of each other, and the injection duct is produced between the blind tunnel void and the elongate part of the communication space.

On the other hand, if the cost of producing a cavity is to be reduced or the range of forms produced increased, the injection and extraction ducts may be disposed substantially coaxially, such that one of these ducts is located in the centre and is surrounded by the other, at least over part of its axial length. In this case only one hole has to be excavated in order to produce the two ducts.

The invention will be understood more clearly from the

following description of preferred embodiments which is given by way of example only and with reference to the appended drawings, wherein:

Figure 1 shows in section a first form of a cavity void made in a salt layer;

Figure 2 shows in section a first cavity form obtained from the void of Figure 1 after excavation by dissolution of some of the salt present in the salt layer;

Figure 3 shows in section a second cavity form obtained after excavation by dissolution of some of the salt present in the salt layer; and

Figure 4 shows in section a third cavity form obtained after excavation by dissolution of some of the salt present in the salt layer.

Figure 1 shows a salt layer 1 in stratified form and comprised between two layers of other minerals present in the ground 10. An injection duct 16 and an extraction duct 18 are disposed in two shafts, after excavation thereof, substantially vertically between ground level and a cavity void 1a excavated in the salt layer 1.

These ducts have one end 16a, 18b located at ground level and one end 16b, 18a located in the cavity void 1a. The ends 16b, 18a located in the cavity void 1a are connected by a communication space void 4. In this case, the communication space void 4 has been drilled proceeding from the duct 18. The drilling axis 13 is shown in broken lines. The diameter of the void is approximately 6 cm and preferably less than 10 cm.

The communication space void 4 has an elongate, substantially rectilinear and horizontal part 4c between an end part 4b, connected to the extraction duct 18, and a further end part 4a surrounding the injection duct 16 over part of its length, in the vicinity of its end 16b which forms a point of injection into the cavity.

A void 2 for a blind tunnel is produced by extending the elongate part 4c of the communication space void 4 beyond the injection duct 16. This blind tunnel void 2 therefore comprises a closed end 2b and an open end 2a communicating with the communication space void 4. The open end 2a overhangs the injection point 16b, such that the open end 2a is disposed in the vicinity of the injection point 16b and the lower part of the open end 2a is higher than the injection point 16b.

Here, the void 4c of the elongate part of the communication space and the blind tunnel void 2 are substantially horizontal. They could also be slightly inclined. In this case, owing to the higher density of the brine relative to the water injected, the open end of the blind holes must of necessity be lower than the closed end and, likewise, the elongate part of the communication space must be lower at the extraction duct end than at the injection point end.

In Figure 2 a solvent (in this case water) is injected as shown by the arrow 17 via the end 16a of the injection duct 16. The water emerges from the duct 16 at the injection point 16b where it is injected into the end 14a of the communication space

as illustrated by the arrows 15a. This communication space, like the cavity as a whole, is entirely or at least almost entirely filled with water and brine. Since the water injected is less dense than the brine, it rises to the upper part of the cavity 11a. The water is injected at a pressure which is slightly greater than the pressure prevailing in the cavity.

The injected water circulates from the end 14a of the communication space towards the elongate part 14c of the communication space 14 and the blind tunnel 12. The water is not introduced owing to the pressure at which it is injected into the blind tunnel but under the effect of a flow created by the dissolution of the salt.

As illustrated by the arrows 15c, 15e, the water filling this cavity excavates the salt layer by dissolving the salt such that, after excavation, the communication space and blind tunnel voids 4, 2 form the communication space 14 and the blind tunnel 12, of which the widths, lengths and heights are greater than their respective void versions. The salt-charged water forming brine then circulates in the lower parts of the communication space 14 and of the blind tunnel 12, as shown by the arrows 15d, 15f.

The brine passes from the blind tunnel 12 towards the elongate horizontal part 14c of the communication space 14, such that the brine formed in the blind tunnel is recovered in the communication space so as to be extracted therefrom.

By applying an injection pressure which is greater than the extraction pressure, the brine circulates from the elongate part 14c of the communication space 14 towards the duct 18 via the end 14b of the communication space 14, as shown by the arrow 15b.

The blind tunnel 12 communicates with the communication space 14 solely via the open end, which enables the blind tunnel to be flooded with water by introducing water thereinto and recovering the brine formed by dissolution of the salt in the blind tunnel.

In Figure 3 the parts corresponding to those in Figure 2 are denoted by the same number increased by 10. This Figure essentially differs from Figure 2 in that the injection duct 26 and extraction duct 28 are coaxial. Since the injection duct 26 descends the furthest in the cavity 21a, it is located on the

interior and the extraction duct 28 is located on the exterior. The extraction duct 28 surrounds the injection duct over the major part of its length.

Owing to this particular configuration, the communication space here no longer has a horizontal elongate part and is produced entirely around the injection duct 26 between the ends 26b, 28a of the injection and extraction ducts. The communication space void can easily be drilled at the same time as the extraction duct is drilled. The axis 23 of the blind tunnel void is shown in broken lines.

Water and hence brine are circulated by means of a compression pump 30 which injects water under pressure into the injection duct 26 as indicated by the arrow 27.

In Figure 4 the parts corresponding to those in Figure 3 are denoted by the same number increased by 10. This Figure essentially differs from the preceding Figure in that a second blind tunnel void 43 is provided. This Figure illustrates the production of multiple blind tunnels 32, 42 in fluid communication with the communication space 34 via their open ends 32a, 42a.

The water injected via the injection point 36b rises since it is less dense than the brine present in the cavity and since the injection point is located below the open ends 32a, 42a of the blind holes. The water is then distributed between the various blind tunnels and excavates them, becoming charged with salt as it does so. The resultant brine then tends to descend in the end 34a of the communication space, as illustrated by the arrows 35c. In practice, the flow 35a of injected water guides the brine towards the end 38a of the extraction duct 38, as illustrated by the arrows 35b. The brine is then extracted via the extraction duct 38.

In this Figure 4 the water and hence the brine are circulated by means of a suction pump 40 which draws in the brine by means of the extraction duct 38, as illustrated by the arrow 39.

It will be appreciated that the invention is in no way restricted to the embodiments described above. The injection and extraction ducts could be inverted, for example, without thereby modifying the invention.

CLAIMS

1. Process for excavating by dissolution an underground cavity in a thin salt layer, the process comprising the following steps:

- producing an injection duct, an extraction duct, a void for a communication space which places the injection and extraction ducts in communication, and at least one void for a blind tunnel such that:
    . the blind tunnel extends between an open end and a closed end; and
    . the blind tunnel communicates via its open end with the communication space;
- then injecting via the injection duct a salt solvent into the communication space in order to excavate the cavity by dissolution of the salt on contact with the solvent; and
- then extracting via the extraction duct the brine formed by the dissolution of the salt;

wherein, in order to excavate the cavity, the blind tunnel is also excavated by circulating solvent in this tunnel, making the solvent pass via the open end of the tunnel from the communication space into the tunnel and recovering the resultant brine so that it can be extracted therefrom.

2. Process according to claim 1, wherein the closed end thereof is disposed at a level which is higher than or substantially the same as that of the open end.

3. Process according to Claim 1 or 2, wherein the open end of the blind tunnel void is produced such that it overhangs the communication space void at the point where they are connected.

4. Process according to Claim 1 or 2, wherein:

- the open end of the blind tunnel void is provided in the vicinity of the injection duct; and
- the solvent is circulated in the injection duct, emerges therefrom via an end forming the point of injection into the cavity; and
- the blind tunnel void is produced such that its open end overhangs the injection point.

5. Process according to any one of claims 1 to 4, wherein the injection duct and extraction duct are disposed substantially coaxially such that one of these ducts is located in the centre and is

surrounded by the other, at least over part of its axial length.

6. Process according to any one of claims 1 to 4, wherein:

- the injection duct and extraction duct are produced at a spacing from each other;
- an elongate part is provided in the communication space void; and
- the blind tunnel void and the elongate part of the communication space void are produced substantially as an extension of each other, and the injection duct is produced between the blind tunnel void and the elongate part of the communication space void.

7. Process according to any one of claims 1 to 6, wherein a plurality of blind tunnel voids are produced connected to the communication space.

8. Process according to any one of claims 1 to 7, wherein the blind tunnel void has a diameter of less than 10 cm.

9. Cavity obtained by implementing the process according to any one of claims 1 to 8.

ABSTRACT

The invention concerns a process for excavating by dissolution an underground cavity in a thin salt layer, in order to store a fluid therein.

According to the invention, the process comprises the following steps:

- producing an injection duct (16), an extraction duct (18), and a void (4) for a communication space (14) which places in communication the injection and extraction ducts;
- producing at least one blind tunnel void (2) communicating with the communication space so as to enable the solvent to circulate and the salt to dissolve in the blind tunnel;
- injecting via the injection duct a solvent in to the communication space; and
- extracting via the extraction duct the brine formed by the dissolution of the salt on contact with the solvent.

The advantage of this solution is that the layer excavated has a mechanically stable shape and a larger volume and is produced more cheaply than with the prior art.

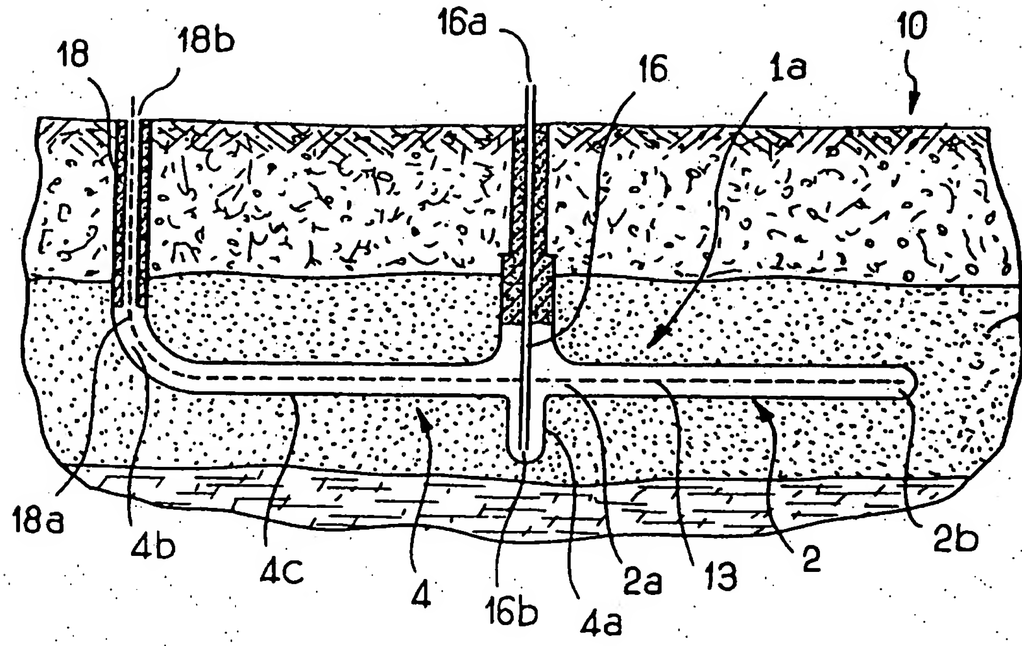

16a
18
18b
16
1a
10
1
18a
4b
4c
4
16b
4a
2a
13
2
2b

FIG_1

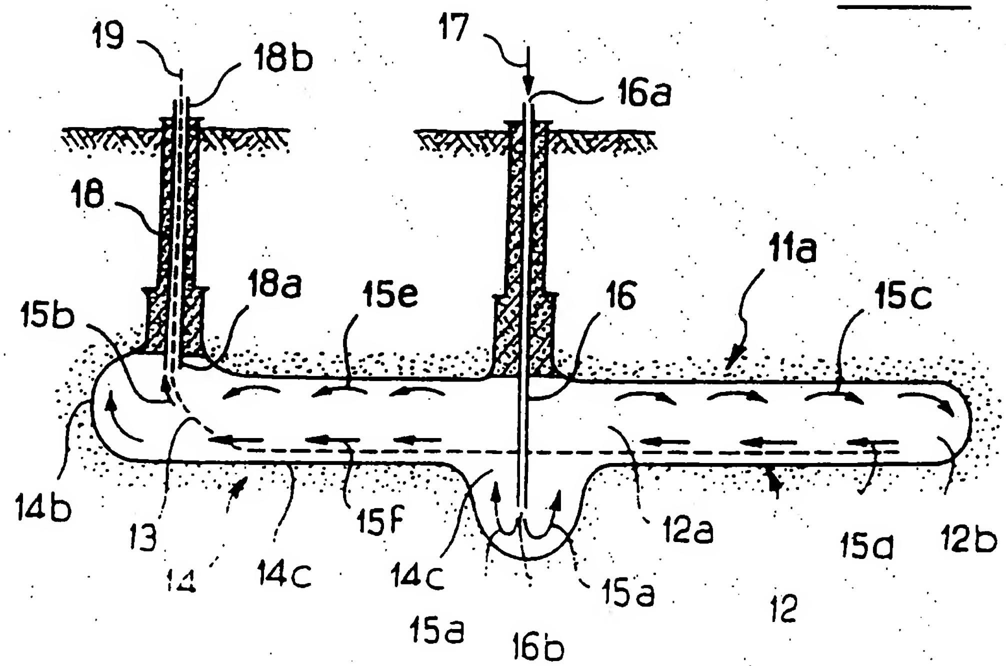

19
18b
17
16a
18
11a
15b
18a
15e
16
15c
14b
13
14
14c
15f
14c
15a
16b
15a
12a
15a
12
12b

FIG_2

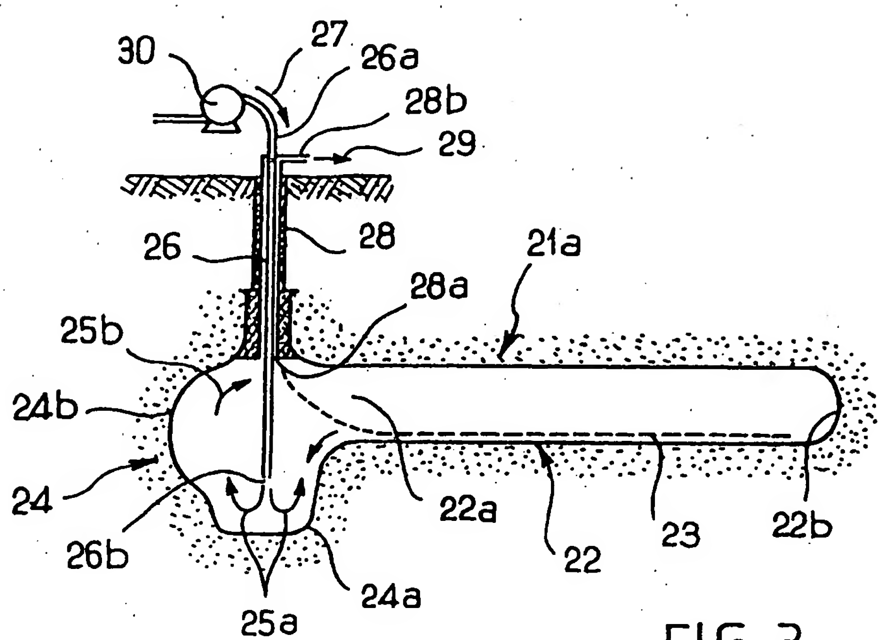

30
27
26a
28b
29
26
28
21a
28a
25b
24b
24
26b
22a
22
23
22b
24a
25a

FIG_3

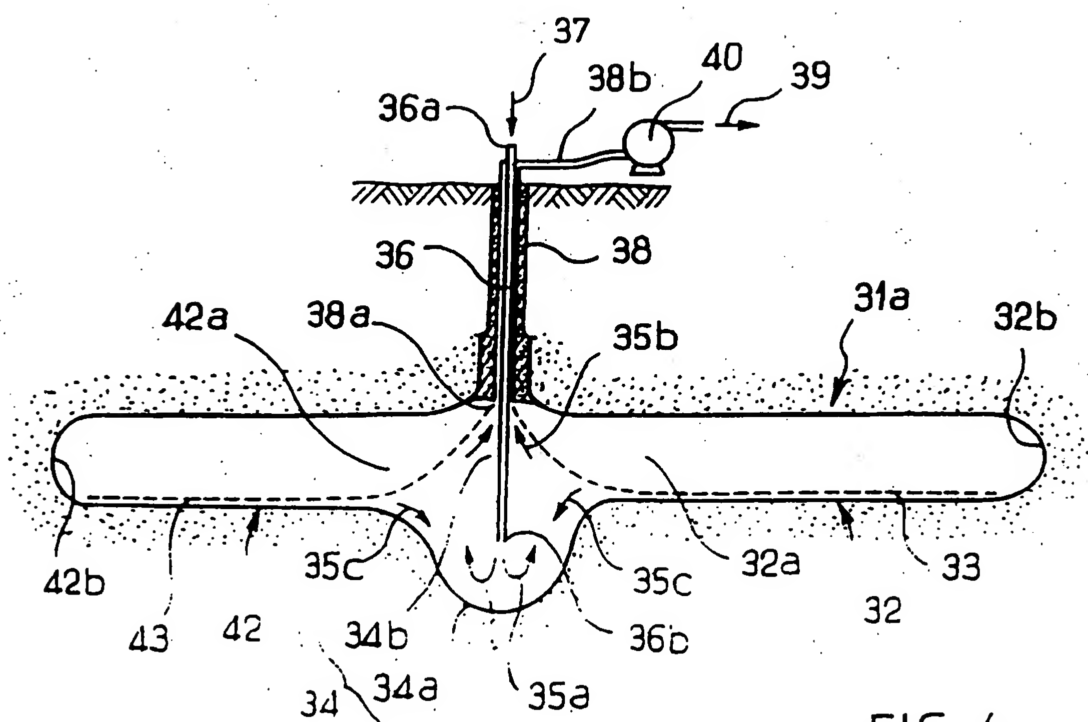

37
36a
38b
40
39
36
38
31a
42a
38a
35b
32b
35c
35c
32a
33
42b
43
42
34b
36b
32
34
34a
35a

FIG_4